Sedimentary Geology 300 (2014) 62–85

Contents lists available at ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

Component-specific petrographic and geochemical characterization of fine-grained carbonates along Carboniferous and Jurassic platform-to-basin transects

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ARTICLE INFO

Article history:
Received 13 May 2013
Received in revised form 9 November 2013
Accepted 13 November 2013
Available online 22 November 2013

Editor: B. Jones

Keywords:
Fine-grained carbonates
Micrite
Geochemistry
Diagenesis
Carboniferous
Jurassic

ABSTRACT

Fine-grained carbonates are present throughout much of the geological record and are widely used as geochemical archives, even though their origin and diagenetic pathways remain poorly understood. Here, petrographical and geochemical properties of granulometrically separated component spectra of marine mudstones sampled along two proximal-to-distal transects (Carboniferous of Spain and Jurassic of Morocco) are documented. These settings represent end members in terms of platform geometry, steep flanked versus gentle ramp, and the aragonite versus calcite sea mode. The data from Spain reveal a bimodal organization of microcrystalline carbonate isotope values from platform top and slope and toe-of-slope settings. The data from Morocco lack a clear spatial and bathymetrical pattern. The significance of the complex, site-specific biological and physico-chemical parameters is emphasized. Mudstones have been separated in granulometric fractions of 8–5, 5–3 and <3 μm respectively, and resulting particle classes are described and interpreted in terms of their origin and diagenetic pathways. Fine-grained carbonate particles from both sites show remarkably similar size and crystallographic features. Their isotopic composition reflects the volumetrically proportion and component-specific geochemical signature of each particle class. Decreasing particle size classes are characterized by decreasing isotope values. This might be due to an enhanced diagenetic reactivity of the finest micritic particles to diagenetic processes. This implies that stratigraphic differences in mean fine carbonate grain sizes may trigger shifts in isotope values. Mean bulk and mean component-specific isotope ratios from the two case settings differ by about 0.5‰ for carbon and 0.7‰ for oxygen. The results shown here are of general significance for those concerned with fine-grained carbonates-based chemostratigraphy and environmental analysis.

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1. Introduction

Carbonate ooze, or microcrystalline carbonate, its lithified counterpart (Folk, 1959), forms a main constituent of limestones throughout much of Earth's history. Despite considerable research (for example Blackwelder et al., 1982; Friedman, 1964; Immenhauser et al., 2002; Keim and Schlager, 1999; Macintyre and Milliman, 1970; Milliman et al., 1985; Reid et al., 1990; Turpin et al., 2012), the origin of fine-grained carbonates remains poorly known and a major challenge in carbonate sedimentology. This is due to the small size of particles and crystals but also because carbonate fines are polygenic in origin and particle sources and mineralogies commonly depend on the environment of formation and the geological period considered.

In modern tropical carbonate environments, such as the Bahamas, the origin of carbonate ooze particles can often be determined from the direct observation or sedimentological context. This is mainly due to the absence, or the only mild degree, of diagenetic alteration (Boardman and Neumann, 1984; Droxler and Schlager, 1985; Gischler et al., 2013; Heath and Mullins, 1984; Rendle-Bühring and Reijmer, 2005; Schlager and Chermak, 1979; Schlager et al., 1994). In contrast, in ancient environments, the source of the often altered carbonate fines is poorly constrained, and can include the platform top, the slope, the water column or plankton (Riding, 2000; Schlager et al., 1994; Shinn et al., 1989; Swart and Eberli, 2005; Turpin et al., 2008, 2011).

Nevertheless, despite the limited knowledge regarding their origin and subsequent diagenetic history, mudstones form the backbone of numerous geochemical studies dealing with the past carbon cycle, palaeo-environmental reconstruction or chemostratigraphy (Coimbra et al., 2009; Föllmi et al., 1994; Gale, 1993; Immenhauser et al., 2008; Jenkyns and Clayton, 1997; Renard, 1985, 1986; Renard et al., 2007; Scholle and Arthur, 1980; Stoll and Schrag, 2000).

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0037-0738/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.sedgeo.2013.11.004

A limited number of studies have assessed the individual geochemical signatures of separated fine-grained carbonate fractions from different geological time intervals to evaluate their origin (Beltran et al., 2009; Minoletti et al., 2005; Renard et al., 2007; Turpin et al., 2011, 2012) and the relevant significance of each fraction on the bulk isotopic signature. Several dominant parameters have changed throughout Earth history and merit attention when dealing with fine-grained carbonates. These are: (i) changes in platform morphology and biota (Ahr et al., 2003; Crevello et al., 1989; Pomar and Hallock, 2008; Schlager, 2003; Simo et al., 1993; Wilson, 1975; Wood, 1999; Zhuravlev, 2001), and (ii) secular changes of the seawater chemistry and evolutionary aspects (Palaeozoic neritic/Mesozoic pelagic domains; Riding and Liang, 2005; Sandberg, 1983; Stanley, 2006; Stanley and Hardie, 1998) and climate modes (greenhouse/icehouse conditions; Frakes et al., 1992). These parameters and their complex interplay, including thermodynamically metastable aragonite and magnesian calcite (Böttcher and Dietzel, 2010), form the core of the 'fine-grained carbonate problem'.

Two settings, representing end-members in several aspects, were examined for this project. One is an extensively studied, steep-flanked Carboniferous (Moscovian) platform in Asturias, Northern Spain (Bahamonde et al., 1997, 2004; Della Porta et al., 2004; Immenhauser et al., 2002, 2008; Kenter et al., 2003, 2005; van der Kooij et al., 2007, 2009). The well-constrained data set available is used to place our findings in a larger sedimentological and palaeoceanographic context. The other case example comes from a less well-investigated Jurassic (Alenian) rimmed ramp transect in the High Atlas of Morocco (Amour et al., 2012; Christ et al., 2012; Pierre, 2006; Pierre et al., 2010). Here, the limitations of granulometrical studies without a well-defined sedimentological and palaeoceanographic framework become obvious.

The aim of this study is to characterize the origin, mineralogy, crystal morphology, and geochemistry of fine-grained carbonate particles along the two fossils platform-to-basin transects. Three main research questions guided the work: (i) Are bulk geochemical data reflected, within error bars, by the various component classes forming the marine carbonate fines analyzed, or, alternatively, are bulk geochemical data the geochemical average of potentially very different isotope and elemental signatures of different component classes? (ii) Does fine-grained carbonate composition changes, perhaps in a predictable manner, along platform-to-basin transects? (iii) To which degree differ fine-grained carbonates deposited in an aragonite sea (Moscovian of Spain) from those deposited in a calcite sea (Aalenian of Morocco)?

2. Case studies

2.1. Pennsylvanian of Northern Spain, Cantabrian Mountains

2.1.1. Geotectonic setting

The study area at the Sierra del Cuera forms part of the Cantabrian Zone and comprises the northwestern part of the Hercynian orogen in the Iberian massif (Fig. 1A). The Sierra del Cuera limestones were originally deposited at latitudes between 10 and 20° south and represents one of the best studied most intact and complete outcrops of a large Pennsylvanian carbonate platform worldwide (Fig. 2; Bahamonde et al., 1997, 2004; Della Porta et al., 2002, 2004; van der Kooij et al., 2009).

The carbonate transect studied here lies within the Picos de Europa Formation (Moscovian; Fig. 1B). In the Late Moscovian–Early Kasimovian, the platform was affected by Variscian compression and deformed into a set of imbricate thrust sheets with an east–west orientation (Marquínez, 1989). The dip of the bedding planes within the carbonate platforms varies between 70 and 90° but commonly approaches vertical.

2.1.2. Depositional architecture and facies

Previous work (Bahamonde et al., 1997, 2004; Della Porta et al., 2003, 2004; Immenhauser et al., 2002, 2003; Kenter et al., 2005; van der Kooij et al., 2007, 2009) documents five general platform physiographic zones: inner and outer platform, upper slope, lower slope, and toe-of-slope to basin (Fig. 2). The inner and outer platforms are dominated by (peloidal) skeletal packstones and wackestones. The upper to mid-slope region is dominated by in situ microbial boundstones intercalated by red-stained intervals and skeletal lenses. The lower slope is

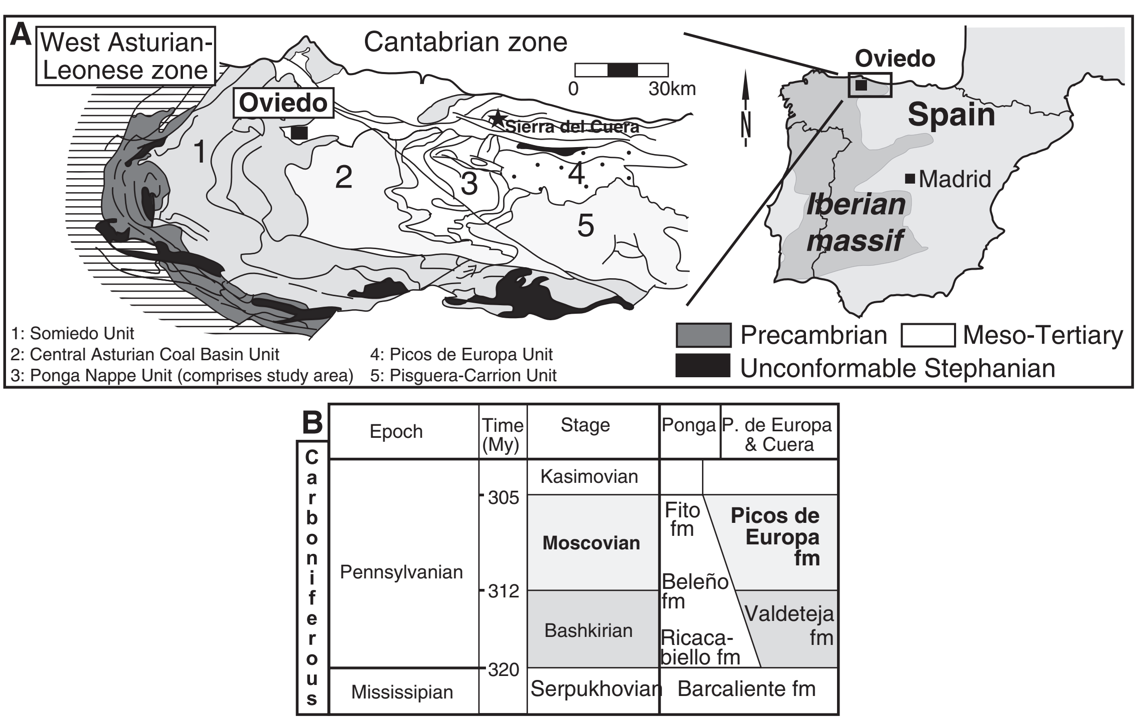

Fig. 1. A: Map of Spain and study area with the geotectonic overview of Cantabrian Zone and major tectonic units (modified after Bahamonde et al., 1997). B: Geological timescale with indication of Sierra del Cuera unit (carbonate slope) and the laterally exposed Ponga Nappe (basin) as mentioned in van der Kooij et al. (2009). The time scale is after Menning et al. (2006).

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